TR-01-912

AIR WAR COLLEGE

RESEARCH REPORT

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No. AU-AWC-86-215

F-16 DIGITAL TERRAIN SYSTEM: CONCEPT OF OPERATIONS AND SUPPORT

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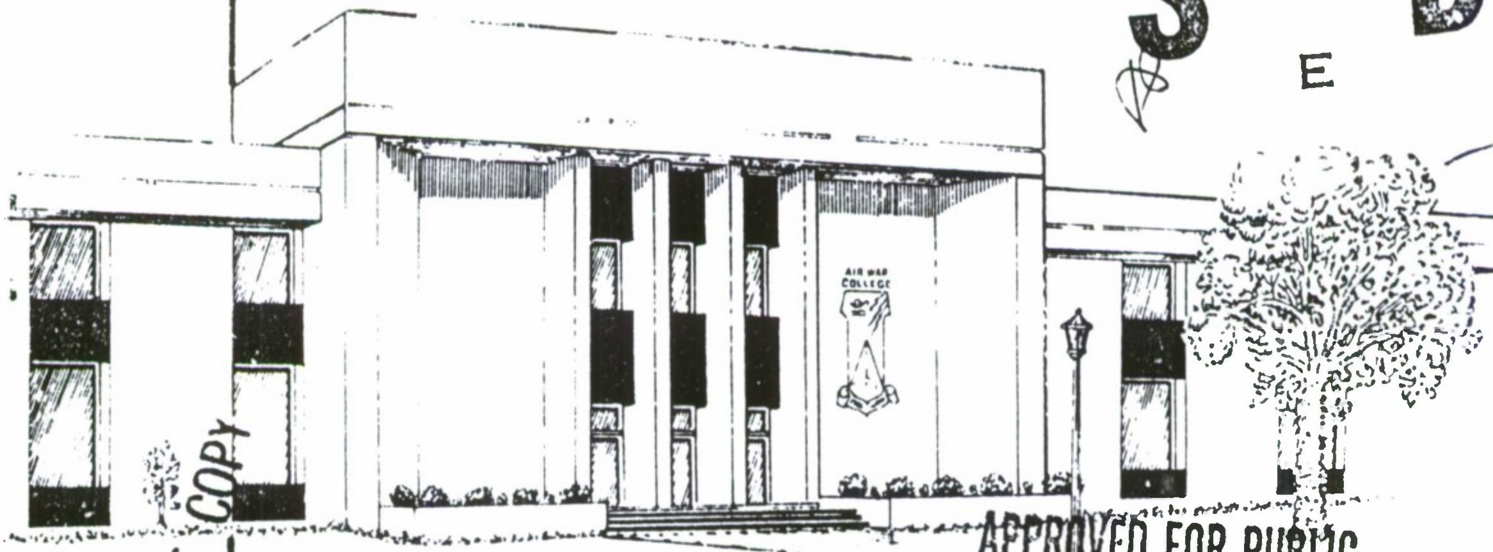

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UNITED STATES AIR FORCE
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A RESEARCH REPORT SUBMITTED TO THE FACULTY

IN

FULFILLMENT OF THE RESEARCH REQUIREMENT

Research Advisor: Lt Col Harry F. Johnson, USAF

MAXWELL AIR FORCE BASE, ALABAMA

March 1986

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AIR WAR COLLEGE RESEARCH REPORT ABSTRACT

TITLE: **F-16 Digital Terrain System Concept of Operations and Support**

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This report presents a concept of operations and support for an F-16 equipped with a digital terrain system (DTS). The DTS uses stored digital, three-dimensional terrain data to provide a variety of high-payoff functions. By overlaying the terrain data with route information, threats, and cultural features, it is possible to display to the pilot all required map information. Besides the cockpit map display system, additional DTS functions include automated mission planning, inflight retargeting, autonomous navigation, and ground proximity warning. These capabilities promise to reduce pilot workload by providing a single-glance tactical situation overview and to allow the pilot to know exactly where he is at all times in flight to better avoid threats and make maximum use of terrain masking. In an operational environment with an increasingly sophisticated threat and a fighter with increasing demands on the pilot, the DTS offers the potential to increase survivability and lethality by enhancing pilot situational awareness and reducing pilot workload. A significant part of this pilot workload reduction will be achieved by automating mission planning on the ground to include preprogramming many of the pilot selectable features such as map scale, changes from plan view to perspective view, changes in cultural features to be shown, and sensor cueing against specific targets (sensor prepointing). The capability improvements offer significant benefit not only for air-to-surface missions but for air-to-air missions as well.

Although the operational concepts are designed for the F-16, the concepts are general enough to have applicability to any aircraft with a similar mission. The mission phases presented include mission planning; ground operations; low-level ingress and egress; air-to-surface operations both conventional and nuclear; air-to-air operations; and routine flight operations.

DTS ground

The support concept for the DTS is two-level--base and technical repair center. The system design concept is modular with extensive built-in-test (BIT); modules identified by the

BIT for removal on the flightline (on-equipment) will be sent directly to the technical repair center for repair. At the technical repair center, the module will either be repaired and returned to the field or disposed of.

The major conclusions of the report are: the three-dimensional characteristics of the DTS provide significant capabilities in both planning and flight operations, the integrated mission planning system to support the automated mission planning station (AMPS) offers increased efficiencies and effectiveness in mission planning, and the DTS integrated with other aircraft systems improves mission effectiveness while reducing pilot workload.

BIOGRAPHICAL SKETCHES

Colonel Paull C. Burnett (M.S., Purdue University, and B.S., United States Air Force Academy) is a fighter pilot with over 2500 hours of fighter time including 800 hours in the F-16A/B/C/D and F-16XL aircraft. His previous assignment was as Test Director of the F-16C/D Initial Operational Test and Evaluation (IOT&E) and F-16XL Operational Test and Evaluation (OT&E) Programs, Edwards Air Force Base (AFB), California. In prior assignments, he served as Commander of the 35th Tactical Fighter Squadron (TFS) at Kunsan Air Base (AB), Republic of Korea, and Operations Officer of the 34th TFS at Hill AFB, Utah. In addition, he has been heavily involved in the F-16 program since its inception serving both as an F-16 action officer at Headquarters Tactical Air Command (TAC) and as officer-in-charge of F-16 conversion both at Hill AFB and Kunsan AB. He is a graduate of the National Security Management Course, Air Command and Staff College, and Squadron Officer School.

Colonel Manuel W. Garrido (M.P.A., Golden Gate University, and B.S., Electrical Engineering, New Jersey Institute of Technology) has a tactical background in the F-4 and F-16 aircraft. He has over 2700 flying hours with 2000 hours in the F-4 including 195 combat missions. Prior to attending the Air War College, he served as the Assistant Director of Operations, 474th Tactical Fighter Wing (TFW), Nellis AFB, Nevada. Prior assignments included the first F-4E squadron (the 40th TFS), the Combat Mecca project officer (LORAN in the F-4) at the Tactical Air Warfare Center, instructor pilot at Ubon AB, Thailand, and F-16 Operations Advisor to the Imperial Iranian Air Force. He has also had staff tours at Headquarters Pacific Air Forces (PACAF), Headquarters TAC, and 25th North American Air Defense Region, as aide to the commander. He is a graduate of the National Security Management Course, Combined Air Warfare Course, Air Command and Staff College, and Squadron Officer School.

Colonel Ronnie K. Morrow (B.B.A., University of Texas, and M.M.A.S., Army Command and General Staff School) has pursued a career primarily in operations and training. His background includes numerous instructor and operational tours in both the F-4 and F-16. His last assignment was as the Director of Standardization/Evaluation for 12th Air Force (AF), Bergstrom AFB, Texas, where he was responsible for the evaluation of all fighter flying operations in 12th AF. Prior to that he served as squadron commander and assistant director of operations of the 50th Tactical Fighter Wing (TFW), Hahn Air Base, Germany, and was involved in the conversion of the 50th TFW from the F-4 to the F-16--the first F-16s in United States Air Forces Europe (USAFE). Prior assignments included Tactical Air Command (TAC), Air Training Command (ATC), Pacific Air Forces (PACAF), and the Pentagon. He is a graduate of the National Security Management Course, US Army Command and General Staff College, Air Command and Staff College, and Squadron Officer School.

Colonel Bartow C. Tucker (M.S., Purdue University, and B.S., United States Air Force Academy) is a graduate of the USAF Test Pilot School and has pursued a career primarily in aircraft and aircraft systems development with operational flying experience in the HC-130 and T-38. His previous assignment was as Director of Development Programs in the F-16 System Program Office, Aeronautical Systems Division. Responsibilities included planning and implementing capability improvements (both production incorporation and retrofit) for all F-16 models. It was in this position that he was first exposed to digital terrain technologies as a potential candidate for transition from the laboratory to production incorporation. Prior assignments included squadron commander and assistant deputy commander for operations in the 4950th Test Wing, Wright-Patterson AFB, Ohio, and two tours in flight test at Edwards AFB, California. He is a graduate of the Armed Forces Staff College, Air Command and Staff College, and Squadron Officer School.

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PREFACE

There is not presently a stated Tactical Air Forces requirement for the Digital Terrain System (DTS) on the F-16. We chose the F-16 for this report because of the authors' familiarity with the aircraft and because the DTS is complementary to the F-16's design and dual roles--air-to-air and air-to-surface. The concept of operations and support presented is, however, is generally applicable to any fighter with one or both of these missions.

The concepts for the operational employment of a Digital Terrain System (DTS) on an F-16 are at this point notional. The functions discussed are those which the authors believe to have the highest payoff. Displays presented are for conceptual purposes only

The authors wish to express their appreciation to the following agencies and companies for their unselfish contributions to this effort:

Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio
Anacapa Sciences, Santa Barbara, California
F-16 System Program Office, Wright-Patterson AFB, Ohio
General Dynamics, Fort Worth, Texas
Harris Government Aerospace Systems Division, Melbourne, Florida
Headquarters Tactical Air Command, Langley AFB, Virginia
Hughes Aircraft Company, El Segundo, California
Logicon, San Pedro, California
Sperry Corporation, Albuquerque, New Mexico
Texas Instruments, McKinney, Texas

CHAPTER I

INTRODUCTION

The capabilities offered by a digital terrain system (DTS) for fighters are based on using stored, digital, three-dimensional terrain data to provide a variety of high payoff functions. By overlaying the terrain data base with route information, threats, and cultural features, it is possible to display to the pilot all required map information. Besides the cockpit map display, additional DTS functions include inflight retargeting, autonomous navigation, ground proximity warning, and automated mission planning to include sensor preprogramming.[1] These capabilities promise to reduce pilot workload by providing a single-glance tactical situation overview allowing the pilot to know exactly where he is at all times in flight and to "look over hills" to better avoid threats and make maximum use of terrain masking. The result will be improved survivability and increased lethality. The DTS functions offer significant benefit not only for air-to-surface missions but for air-to-air missions as well.

The purpose of this report is to provide a preliminary concept of operations and support for use of such a system on the F-16. The operations concept will cover all phases of air-to-surface and air-to-air missions with emphasis on mission planning and employment of each digital terrain system function. Although displays will be shown for conceptual purposes, the purpose of this report is not to define displays but rather to define the broad DTS functions and

[1] Another DTS function could provide low-emission terrain following/terrain avoidance/threat avoidance (TF/TA²) by providing terrain data to the flight control computer thus reducing the radar's high duty cycle required to refresh terrain data. By operating the terrain-following radar at low power or leaving it off, radar signals that are .005% of normal are achievable according to Alan L. Johnson of Texas Instruments Equipment Group [Alton K. Marsh, "Texas Instruments Developing Terrain-Following Aircraft System," Aviation Week & Space Technology (20 May 1985) p. 61]. Because of the technical complexities of integrating this function with the radar, this function will most likely be considered as a preplanned product improvement (P³I). The software for the DTS will be capable of generating TF/TA² profiles based strictly on the digital terrain data which will be provided as a recommended profile to the pilot. For a detailed discussion of this function, see G. W. Cantrell, "Applications of Digital Terrain Data in Flight Operations," (Melbourne, Florida: Harris Government Aerospace Systems Division, [May 1985]), pp. 15-17.

then to specify modes and to describe how they would be used operationally. The support concept will address base-level and depot-level repair. The concept is presented as preliminary because as any new technology is developed and incorporated into a weapons system the concept is refined with increasing experiance. In addition, there may be technological, schedule, or budgetary constraints on the system that are not known at this time.

1-1. *BACKGROUND*

Most of the map information available from a DTS for cockpit display is available from a film reader based system such as those planned for the F-15E, AV-8B, and F/A-18. Like the DTS, these film readers will provide a significant increase in pilot situational awareness[2] and virtually eliminate paper maps from the cockpit (except as a backup). Film reader systems are also capable of accepting route and threat information overlays for color display on a cockpit multifunction display (MFD). To develop these route and threat overlays, a film reader system must be integrated with a ground mission planning station. It would be relatively straightforward to use this mission planning station to also generate Air Force Form 70-type information--headings, distances, times, and fuel required.

Essentially then, a film reader planning station can be thought of as providing two-dimensional mission planning. However, by using threat overlays and with the crewmember or mission planner mentally incorporating the third dimension (terrain height) from map contours, a film reader system allows the crewmember to incorporate terrain masking or shielding in a rudimentary fashion. With a DTS, elevation information can be graphically displayed to the planner and incorporated in computer calculations. But, a more important limitation of a film reader system than the lack of terrain height is that once the data is loaded into the aircraft neither the pilot nor other aircraft systems can interact with the data.

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[2]Situational awareness is defined as the pilot's knowledge of his aircraft status and the tactical situation based on observing and accurately interpreting all information available to him.

These limitations of a film reader are eliminated when a digital terrain data base containing terrain height is incorporated into the aircraft and the mission planning station. But more importantly, the other DTS functions--inflight retargeting, autonomous navigation, ground proximity warning, and automated mission planning--promise to significantly increase mission accomplishment. With both a world-wide terrain data base of sufficient accuracy and the capability to efficiently store the voluminous data base for a tactical mission becoming a reality, it is possible now to think in terms of three-dimensional mission planning and execution.

Two Air Force Wright Aeronautical Laboratory programs are demonstrating important elements of a DTS. The first program is Integrated Terrain Access and Retrieval System (ITARS) which will use stored terrain data to accomplish several of the DTS functions. The contractor is scheduled to deliver two ITARS systems in late 1986. The second program is Survivable Penetration and Attack which will develop terrain-following/terrain-avoidance/threat-avoidance (TF/TA^2) algorithms and an integrated avionics/control system to provide a fighter aircraft the capability to perform low-altitude, high-speed maneuvering, penetration, and attack missions automatically.[3]

1-2 DESIGN PHILOSOPHY

The digital terrain system design philosophy must consider both the operational and support requirements. A key aspect of the total system design will be development of the ground automated mission planning station (AMPS) and integration with the aircraft system--the DTS. Related to mission planning will be the design requirement for a limited mission planning capability from within the cockpit when the AMPS is not available such as when deployed to remote locations or diverted from home station. It should be noted at this point that many of the requirements for a DTS for tactical use are also common for strategic aircraft in low-level operations and this may influence the final design.

[3] "What's Happening in Aeronautics at ASD," Air Force Magazine, January 1986, p. 55.

To achieve the objectives required for the DTS, the system must reduce overall pilot workload. To accomplish this while at the same time introducing a number of new functions into the aircraft will require extensive simulation and flight testing.

In order for the DTS to be compatible with new tactical fighters of the 1990s, as well as the F-16, the DTS must use Pave Pillar[4] compatible architecture and high density packaging techniques which will have the added benefits of minimizing size, weight, power, and cooling requirements while at the same time maximizing reliability and maintainability factors. A Pave Pillar design will also increase flexibility for future growth. The program design language should be the DOD common language, ADA.

To be compatible with the Pave Pillar architecture the DTS must be modular, programmable, fault-tolerant, and incorporate either VLSI (very large-scale integration) or VHSIC (very-high-speed integrated circuit) technology. The system will have built-in test (BIT) which functions both on-line and off-line. Fault isolation will be used to reconfigure the system to compensate for failed components. As the system degrades because of failed components, reconfiguration will consider both type of mission and flight phase. With these capabilities incorporated, the mean time between critical failure (MTBCF) of the map display function can be required to exceed 1000 hours.

With this MTBCF, the system will be designed for two-level maintenance. Modules identified by the BIT for removal on the flightline (on-equipment) will be sent directly to the depot for repair. At the depot, the module will either be repaired and returned to the field or disposed of.

The AMPS will be a fully integrated, interactive system for planning, verifying, and formulating classified and unclassified mission data. Components will include a terminal

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[4] Pave Pillar is a next-generation system of avionics being developed by Aeronautical Systems Division that will use common modules, fusion algorithms across sensor systems, fault-tolerant system architecture, and high-performance reliable component technologies such as VHSIC (very-high-speed integrated circuit).

processor/controller (operator's console), interactive graphics display terminal(s), data storage systems, line printer, map plotter, digitizer, and mini-computer. AMPS will require no increase in mission planning personnel and must allow a complete mission to be planned in 30 minutes.

1-3. *OPERATIONAL ENVIRONMENT*

The operational environment in the 1990s and the next century will increasingly challenge the fighter pilot and his aircraft. Specifically, Soviet acquisition of Western technology as well as application of their own technology to defensive systems will continue to threaten the effectiveness of the F-16, particularly for low altitude penetration. Major upgrades in the Soviet low altitude air defense system are underway now including improved interceptor aircraft, air defense radars, surface-to-air missiles (SAMs), and air defense artillery (AAA) systems. In addition to these qualitative improvements including larger lethal envelopes, the Soviets are making impressive increases in numbers of SAMs deployed. The net result of increased lethal envelope and numbers is a significantly more dense SAM threat.

These major upgrades in the Soviet air defense system will be operational in the 1990s. New early warning and surveillance radars integrated with existing strategic and tactical defense systems will improve detection capabilities. Once detected, the Soviets will have the option to use their IL-76/CANDID AWACS (Airborne Warning and Control System) to vector fighters to the F-16. The CANDID will also offer a significant improvement in Soviet capabilities for early warning against low-flying aircraft. The Soviet frontline fighters of the 1990s--the SU-27/FLANKER, MIG-29/FULCRUM, and the MIG-31/FOXHOUND--will be all-weather, beyond-visual-range, and look-down/shoot-down capable. These aircraft will be armed with look-down/shoot-down compatible air-to-air missiles currently under development--either the long-range AA-9 or the medium-range AA-10. The next line of defense the fighter must penetrate is the layered SAM systems. Here the Soviets are developing and deploying SA-10, SA-11, and SA-X-12 missiles. These missiles will improve the range, mobility and level of control capabilities of the Soviet forces. Improvements are also planned for air defense artillery such as the follow-on ZSU-23/4 widely deployed in the target area. So even in the target area, the fighter pilot will have to remain alert and responsive to the threat.[5]

To counter this increasingly sophisticated threat will require more complex tactics and specific defensive system upgrades. In addition, new missions such as night and under the weather attack will further increase mission complexity and demand more thorough and time consuming preflight planning. Controlling pilot workload will be particularly difficult as additional systems are incorporated into the F-16 to increase its lethality and improve its defensive capabilities. In the F-16 where the workload is already high, extreme care must be exercised to prevent the pilot workload from increasing further. Any aircraft improvements which enhance pilot situational awareness or reduce pilot workload in this increasingly complex environment will increase mission accomplishment and survivability. Therefore, any system which offers the potential for increasing situational awareness and reducing pilot workload demands serious evaluation.

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[5]Information on Soviet force capabilities obtained from U.S., Department of Defense, Soviet Military Power, 1985 (Washington, D.C.: Government Printing Office, April 1985).

CHAPTER 2

OPERATIONAL REQUIREMENT

If the F-16 is to remain viable in a tactical environment where the threat continues to make major increases not only in quantity of air and surface threats but also in quality as well, improvements in the F-16's offensive and defensive capabilities are required. Quantifying the improvement in offensive capability or lethality provided by incorporation of the LANTIRN[6] on the F-16 is relatively easy; similarly, quantifying the increase in defensive capability or survivability provided by upgrading the countermeasures dispenser to the AN/ALE-47[7] is also relatively easy. Because improvements such as these provide a measurable improvement in combat capability, support is widespread in the government and defense community and many such improvements are planned. But it is also possible to improve the F-16's mission performance in day, night, and weather air-to-surface missions and air-to-air missions by improving the pilot's situational awareness and reducing his task loading. A DTS incorporated on the F-16 will not only add new capabilities such as autonomous navigation but will also allow the pilot to use the F-16's total capability more effectively by increasing the time he has available to concentrate on the highest priority tasks.

Although it is difficult to quantify the increase in capability from eliminating navigation errors, most pilots feel strongly that errors result in a significant increase in workload. This subjective feeling was validated in a pilot opinion survey of 12 experienced pilots which found that ". . . pilot errors were considered to be a significant source of workload and stress by experienced pilots. Furthermore, errors were considered to have a negative impact on subsequent

[6] LANTIRN (Low-Altitude Navigation and Targeting Infrared for Night System) is an integrated system which displays forward-looking infrared (FLIR) video to the pilot. It will provide the F-16 with the capability to conduct close air support and interdiction missions at night and under adverse conditions.

[7] The AN/ALE-47 is a countermeasures dispenser system capable of interfacing with the radar warning receiver, jammer, and other aircraft systems to provide threat adaptive programming of expendables in multiple threat environments.